Overview of Special Issue: “Geographical Investigation on the 2011 Great East Japan Earthquake Disaster, Focusing on the Regional Diversity of Tsunamis and Geo-hazards”

Yasuhiro SUZUKI*, Yohta KUMAKI**, Toshihiko SUGAI*** and Nobuhiko SUGITO****

The 2011 off the Pacific coast of Tohoku Earthquake, with a moment magnitude of 9.0, was the most powerful earthquake recorded in Japan during the last several hundred years. The earthquake and subsequent tsunami caused extensive and severe damage, and the event has become known as the 2011 Great East Japan Earthquake Disaster.

The myriad problems that resulted from the 2011 earthquake disaster exemplified the limitations of scientific understanding of the disaster itself, as well as the increasing vulnerabilities caused by current changes in Japan’s social structures. While it is essential to examine such problems from a multidisciplinary viewpoint, the region’s geographical traits should be considered an important factor. This special issue examines the geographical distribution of disasters, and discusses regional disparities observed among tsunamis and other geo-hazards, ultimately postulating that disasters should be considered a primary subject of geography.

There are many unresolved questions regarding the tsunami that followed the 2011 earthquake, which is considered to be the most severe subsequent hazard. For example: (1) What principal factors determined the large regional differences in run-up height and inundation area of the tsunami? (2) What were the conditions in areas where the tsunami had a higher run-up height, and what conditions brought about an overlapping lower long-wavelength and higher short-wavelength tsunami? (3) What were the essential differences between this tsunami and those in 1896 and 1933? (4) What is the detailed structure of the tsunami source model? (5) What were the conditions in areas where many lives were lost? (6) What were the flow and direction of the tsunami? (7) How did the tsunami influence topography (and how was the tsunami generally controlled by topography)?

Furthermore, severe liquefaction occurred in a much wider area than was anticipated. To avoid this problem in the future, the following questions should be answered: (1) How inaccurate was the hazard map in anticipating the occurrence of liquefaction? (2) What were the reasons for the forecasting errors, and were they specific to the huge earthquake? (3) Were there any geomorphological or geological conditions that controlled the general distribution of liquefaction across a wider area? (4) How can the liquefaction hazard map be improved?

Recently, disaster-related geographical information such as Digital Elevation Models (DEMs), land conditions, surface geology, and active fault distribution data have been provided by the government. To promote the efficient distribution

* Disaster Mitigation Research Center, Nagoya University, Nagoya, 464-8601, Japan
** School of Letters, Senshu University, Kawasaki, 214-8580, Japan
*** Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, 277-8563, Japan
**** Faculty of Humanity and Environment, Hosei University, Tokyo, 102-8160, Japan
of such information, those involved in disaster prevention should consider: (1) the resolution required to most accurately predict a disaster; (2) the level of accuracy that can be guaranteed with available technology; and (3) if it is possible to evaluate the history of artificial landform modification; in particular, to specify precise boundaries between filling and cut areas.

Following the 2011 earthquake and tsunami, disappointment was expressed with scientific forecasting capabilities and technological countermeasures. It is, therefore, essential to reconsider the concepts and goals of disaster prevention. While the 2011 $M_{9}$-magnitude earthquake disaster was regarded as “unanticipated,” the possibility of its occurrence had already been mentioned by the government; therefore, “unanticipated” did not mean “impossible to anticipate” but meant “be excluded from preparing countermeasures” (Suzuki, 2011). To avoid a repeat of such an “unanticipated” problem, the limitations of scientific forecasts should be fully understood when discussing future countermeasures.

The Central Disaster Management Council of Japan (2011) suggested that the maximum size of an earthquake should be considered theoretically as a probability to avoid being ill-prepared. This policy is important, however, it is generally difficult to determine the theoretical maximum of a future earthquake or other natural disaster.

The possibility that an impending hazard may be larger than indicated on hazard maps should be communicated to the public carefully, to avoid misleading society. First, however, it is more important to understand the regional diversity of disaster phenomena when discussing disaster mitigation.

This special issue gathers the results of significant research conducted by geographers after the 2011 earthquake, and examines the geographical diversity and regionality of related disasters. This examination may help to explain unique characteristics of the earthquake and the fundamental reasons for damage expansion.

Furthermore, the reconsideration of active faults located in the areas of nuclear power plants gained traction after the severe accident at Fukushima nuclear plant in March 2011. Some geographers remain engaged in this work and actively recommend strategies to the government. While it is considered to be one of the most important public issues, the current special issue does not directly address this subject.

Sugito et al. (2015) present a methodology used to produce a Tsunami Run-up Height Map for the tsunami associated with the 2011 earthquake, including corrections to horizontal shifts of ortho-photos taken immediately after the event using a Helmert transformation. The map shows polygon data of inundation areas with elevation data at each point, as obtained from a GIS analysis of: 1) data collected by the Tsunami Damage Mapping Team, and 2) post-tsunami 2-m mesh and 5-m mesh LiDAR-based DEMs produced by the Geospatial Information Authority of Japan. The study uses the map to discuss in detail spatial variations of tsunami run-up heights, based on: 1) landforms at each site, 2) their directions or magnitudes, and 3) source locations, interference, and wavelengths of the tsunami. The importance of the methodology is emphasized in relation to revealing the detailed run-up height distribution immediately after future tsunamis.

Matsuta et al. (2015) focus on the relationship between tsunami run-up heights and coastal topography at the 1896 Meiji Sanriku, 1933 Showa Sanriku, and 1960 Chilean tsunamis along the Sanriku Coast, indicating that: 1) small bays facing the Pacific Ocean are sensitive to short-wavelength tsunamis, and 2) inner parts of large bays are sensitive to long-wavelength tsunamis. From this perspective, the study examines the distribution of tsunami run-up heights for the tsunami caused by the 2011 earthquake, and implies that source fault models proposed by previous seismological and geodesic analyses should be revised based on geomorphological observations of coastal topography and submarine tectonic landforms.

Based on community-scale statistics from the municipalities of Kamaishi, Kesen’numa, Minami-sanriku, and Yamamoto, Takahashi and Matsuta (2015) discover wide variations in mortality rates among villages affected by the tsunami associated
with the 2011 earthquake. Villages with high mortality rates were located some distance from the sea, whereas those with very few deaths were located much closer to the sea. The study suggests that these differences relate to the interaction of inhabitants with their physical or built environment, and emphasizes the need for a grassroots geographic perspective of the relationship between tsunamis and evacuation.

Koarai et al. (2015) conduct a GIS-based overlay analysis of: 1) tsunami-damaged areas identified from post-tsunami aerial photographs of the 2011 earthquake, 2) inundation-depth data obtained in the field, and 3) data of land usage, land conditions, and LiDAR-based post-tsunami elevations. As a result, the following conclusions are drawn: 1) the level of damage depended on inundation depth, 2) areas of inundation were related to elevation, 3) areas suffering serious damage were within 1 km of the coastline, and 4) coastal landforms and land usage defined the level of damage in landward areas.

To understand tsunami behavior, Hori et al. (2015) focus on the collapse of utility poles on the Sendai coastal plain in relation to the 2011 earthquake. Most of the collapsed utility poles were found in areas within 2 km of the coastline, which corresponded to areas with an inundation depth of 2–3 m or higher, and the collapses were caused by run-up flows. In addition, the area in which collapses occurred was situated more than 2.5 km from the coastline in Yuriage to Kozukahara, Natori City, where there were higher death rates. However, the area in which collapses occurred was 1–1.5 km wide at the southern part of Iwanuma City, and there were fewer deaths in this region. Based on these observations, the study indicates that: 1) the locations and scales of settlements near the coastline defined the amount of tsunami rubble, and 2) the amount of rubble corresponded to spatial differences in the number of collapses of utility poles.

Based on topographic measurements of slope surfaces near the coast, Hayakawa et al. (2015) identify tsunami-derived topographic changes along the rocky Sanriku coast for the 2011 off the Pacific coast of Tohoku earthquake using high-resolution terrestrial laser scanning. A notable finding is that several slope failures developed around the elevations of maximum inundation heights of the tsunami at each site. In addition, small-scale scarps were identified on mountainous bedrock slopes, the topography of which was revealed by the flow of the 2011 tsunami. This implies that repeated devastating tsunamis occurred during the middle to late Holocene. In addition, the study indicates the importance of geomorphic processes derived from the flow of tsunamis in gaining an understanding of bedrock morphology in rocky coastal areas.

Nakano et al. (2015) revise the hazard assessment standard for land liquefaction by combining two existing risk assessment tables. The new standard is based on high-resolution landform classification data derived from land condition data. The study also proposes a comprehensive landform classification and related hazard assessment standard for use in producing a simplified hazard map of land liquefaction on the basis of landform classification data.

From the perspective of geomorphic and geologic history, Sugai and Honda (2015) discuss the effects of alluvial deposits on liquefaction in the Kanto region during the 2011 earthquake, focusing on: 1) the coastal prism (CP), sandwiched between the present and the last glacial river-profiles, and 2) the basal gravel layers (BG) that developed along the bottom of the CP in relation to the last glacial rivers. The inland limit of the large liquefied area roughly coincides with the upstream edge of the long and thick CP. The study also examines the mechanism of liquefaction from the viewpoints of the thickness of the CP and of the seismic behavior of the CP and the BG. In addition, the study implies that a mega-thrust earthquake has the potential to liquefy inland sediment-fill basins beyond the inland limit of the CP, based on an analysis of inland basins that liquefied during the 2011 earthquake.

Une et al. (2015) examine the liquefaction hazard map of Abiko City, Chiba Prefecture, which was one of the most heavily damaged areas in the lower stream region of the Tone River during the 2011 earthquake. The hazard map produced
before the 2011 earthquake failed to adequately predict the sites of liquefaction that occurred during the earthquake, for the following reasons: 1) the 1:50,000-scale landform classification map was used for a smaller-scale classification, 2) artificially filled areas were indicated as artificially modified areas, and 3) land histories that could easily have been exposed using old editions of topographic maps or aerial photographs were not reviewed. By examining these problems, Abiko City has revised the liquefaction hazard map with the assistance of the Geospatial Information Authority of Japan support team.

To estimate seismic risk in artificially modified areas such as residential development land on hills, Ishiguro et al. (2015) present a methodology to determine cut-and-fill boundaries and artificially filled depths, by comparing four types of data obtained from a photogrammetric analysis of old editions of topographic maps and aerial photographs with present-day LiDAR-based 5-m DEMs. Based on this comparison, the study suggests that: 1) all measures of accuracy are within the range specified in the manual by the Geospatial Information Authority of Japan, 2) greater accuracy might be achieved using 1:20,000-scale photographs taken by the Geospatial Information Authority of Japan in 1965, and 3) photogrammetry is useful for determining cut-and-fill boundaries and artificially filled depths.

References


